

TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371U.S. APPLICATION NO. (if known,  
37 CFR 1.53)  
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PCT/JP99/04335INTERNATIONAL FILING DATE  
10 August 1999PRIORITY DATE CLAIMED  
18 January 1999TITLE OF INVENTION  
METHOD AND DEVICE FOR DRYING SUBSTRATE

APPLICANT(S) FOR DO/EO/US --- Tomoo Tsugawa, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
  2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
  3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
  4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
  5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
    - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau)
    - b. ☒ has been transmitted by the International Bureau (see Form 308)
    - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
  6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2))
  7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
    - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau)
    - b. ☐ have been transmitted by the International Bureau.
    - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
    - d. ☒ have not been made and will not be made.
  8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
  9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
  10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).
- Items 11. to 16. below concern other document(s) or information included:**
11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. (w/ copy of PTO-1449 and each reference cited therein and Int'l Search Rept)
  12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
  13. ☐ A FIRST preliminary amendment.
    - ☐ A SECOND or SUBSEQUENT preliminary amendment.
  14. ☐ A substitute specification.
  15. ☐ A change of power of attorney and/or address letter.
  16. ☒ Other items or information:
    - a) PCT Request (PCT/RO/101)
    - b) Cover page of WO 00/42373 with International Search Report (PCT/ISA/210)
    - c) Notification of Receipt of Record Copy (PCT/IB/301)
    - d) Notification Concerning Submission or Transmittal of Priority Document (PCT/IB/304)
    - e) Form PCT/IB/308
    - f) Information Concerning Elected Offices Notified of Their Election (PCT/IB/332)
    - g) Notification of Transmittal of Copies of Translation of the International Preliminary Examination Report (PCT/IB/338)
    - h) Translation of International Preliminary Examination Report (PCT/IPEA/409)

TRANSMITTAL LETTER TO THE UNITED STATES  
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CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER  
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37 CFR 1.5  
**09/889484**

17. ☒ The following fees are submitted:

CALCULATION

PTO USE ONLY

**Basic National Fee (37 CFR 1.492(a)(1)-(5)):**

Search Report has been prepared by the EPO or JPO ..... \$860.00  
International preliminary examination fee paid to USPTO (37 CFR 1.482) ..... \$670.00  
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee  
paid to USPTO (37 CFR 1.445(a)(2)) ..... \$760.00  
Neither international preliminary examination fee (37 CFR 1.482) nor  
international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$970.00  
International preliminary examination fee paid to USPTO (37 CFR 1.482)  
and all claims satisfied provisions of PCT Article 33(2)-(4) ..... \$96.00

ENTER APPROPRIATE BASIC FEE AMOUNT = \$860.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest  
claimed priority date (37 CFR 1.495(e)).

\$ -

Claims	Number Filed	Number Extra	Rate		
Total Claims	10 - 20 =	0	x \$18.00	\$ -	
Independent Claims	4 - 3 =	1	x \$80.00	\$80.00	
Multiple dependent claim(s) (if applicable)			+ \$270.00	270.00	

TOTAL OF ABOVE CALCULATIONS = \$ 1210.00

Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed.  
(Note 37 CFR 1.9, 1.27, 1.28).

\$ 0.00

SUBTOTAL = \$ 1210.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest  
claimed priority date (37 CFR 1.492(f)).

\$ -

TOTAL NATIONAL FEE = \$1210.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an  
appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property.

\$ 0.00

TOTAL FEES ENCLOSED = \$1210.00

Amount to be  
refunded \$

charged \$

- a. ☒ A check in the amount of \$ 1210.00 to cover the above fees is enclosed.  
b. ☐ Please charge my Deposit Account No. 02-4300 in the amount of \$ \_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.  
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required with respect to any deficiency in the above noted "Basic National Fee", or credit any overpayment to Deposit Account No. 02-4300.

SEND ALL CORRESPONDENCE TO:

SMITH, GAMBRELL & RUSSELL, LLP  
1850 M Street, NW - Suite 800  
Washington, DC 20036

Tel: (202) 659-2811  
Fax: (202) 659-1462



SIGNATURE

Michael A. Makuch - 32,263

NAME

REGISTRATION NO.

Date: July 18, 2001

## Specification

Method and Device for Drying Substrate

## Technical Field

The present invention relates to a method and device for drying substrates. More particularly, the present invention relates to a method and device for rapidly drying substrates which are cleaned using cleaning fluid.

## Related Art

From the past, a device having an arrangement which is illustrated in Japanese Patent Publication Gazette No. Hei 6-103686 is proposed as a device for drying substrates (for example, semiconductor wafer or the like) after cleaning of the substrates using cleaning fluid, by relatively lowering the fluid face of the cleaning fluid with respect to the substrates and by supplying drying fluid vapor {for example, isopropyl alcohol (hereinafter referred to as IPA) vapor or the like}.

When the device is employed, a plurality of substrate housed within a processing container

is cleaned using the cleaning fluid, then the drying fluid vapor is introduced within the processing container and the fluid face of the cleaning fluid is lowered, both operations are carried out simultaneously, so that a thin fluid layer of drying fluid is generated on the fluid face of the cleaning fluid. Consequently, the surface of each substrate is rapidly dried using MARANGONI effect.

When the device having the arrangement illustrated in Japanese Patent Publication Gazette No. Hei 6-103686 is employed, not only an introducing passage for introducing drying vapor but also a relief valve (exhaust opening) for exhausting drying vapor are needed for forming a flowing passage of drying vapor within the processing container so that the arrangement becomes complicated and that a dangerous condition is realized in which the drying vapor leak within a factory.

Further, when the device is applied for drying a plurality of semiconductor wafer, the semiconductor wafer is enlarged in size, and an interval of semiconductor wafer is decreased for increasing a number of semiconductor wafer which are processed simultaneously, in recent years. Under such condition, a disadvantage arises in

that intruding of the drying vapor between semiconductor wafers becomes difficult so as to generate a drying mark on the semiconductor wafers.

The present invention was made in view of the above problems.

It is an object of the present invention to offer a method and device for drying substrate in which an exhaust equipment is eliminated or simplified and for smoothly supplying drying fluid.

### Disclosure of the Invention

A method for drying substrate of claim 1 houses substrates within a processing container, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing container with respect to the substrate and by introducing the drying fluid within the processing container, the method comprises steps of,

Introducing drying fluid under a liquid condition within the processing container, and

Injecting the introduced drying fluid onto the fluid face of the cleaning fluid using a nozzle.

A method for drying substrate of claim 2 blows inert gas for atomizing the drying fluid.

A method for drying substrate of claim 3 intermittently introduces the drying fluid within the processing container.

A device for drying substrate of claim 4 houses substrates within a processing container, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing container with respect to the substrate and by introducing the drying fluid within the processing container, the device comprises,

Drying fluid supplying means for introducing drying fluid under a liquid condition within the processing container, and for injecting the introduced drying fluid onto the fluid face of the cleaning fluid using a nozzle.

A device for drying substrate of claim 5 further comprises blowing means for blowing inert gas for atomizing the drying fluid, the blowing means being near the drying fluid supplying means.

A device for drying substrate of claim 6 further comprises control means for controlling the drying fluid supplying means so as to

intermittently introduce the drying fluid within the processing container.

A method for drying substrate of claim 7 houses substrates within a processing container, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing container with respect to the substrate and by introducing the drying fluid within the processing container, the method comprises steps of,

Conveying liquid drying fluid to exhaust opening of a nozzle using carrier gas, and

Simultaneously blowing the drying fluid and the carrier gas from the exhaust opening towards an upper face of the cleaning fluid.

A device for drying substrate of claim 8 houses substrates within a processing container, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing container with respect to the substrate and by introducing the drying fluid within the processing container, the device comprises,

Drying fluid supplying means for conveying liquid drying fluid to exhaust opening of a nozzle using carrier gas, and for simultaneously blowing the drying fluid and the carrier gas

from the exhaust opening towards an upper face of the cleaning fluid.

A device for drying substrate of claim 9 wherein the drying fluid supplying means comprises a first feed pipe for supplying carrier gas to the nozzle and a second feed pipe for supplying liquid drying fluid which is communicated to the halfway of the first feed pipe.

A device for drying substrate of claim 10 wherein the drying fluid supplying means comprises a first feed pipe for supplying carrier gas to the nozzle and a second feed pipe for supplying liquid drying fluid to the nozzle, the first feed pipe and the second feed pipe being independently provided from one another.

When the method for drying substrate of claim 1 is employed, the method houses substrates within the processing container, and dries the surface of each substrate by relatively lowering the fluid face of cleaning fluid within the processing container with respect to the substrate and by introducing the drying fluid within the processing container. During this operation, the method introduces drying fluid under a liquid condition within the processing container, and Injects the introduced



drying fluid onto the fluid face of the cleaning fluid using a nozzle. Therefore, the drying fluid is smoothly introduced between the substrates due to the influence of dead weight of the liquid drying fluid so that the drying fluid is supplied with higher density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid is generated on the cleaning fluid so that drying of the substrates with greatly little drying mark is rapidly realized using MARANGONI effect. Further, the drying fluid is supplied in a liquid phase condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid. Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a result, decrease in cost is realized.

When the method for drying substrate of claim 2 is employed, the method blows inert gas for atomizing the drying fluid. Therefore, disadvantage is prevented from occurrence that droplet of the injected liquid drying fluid becomes too large, so that superior drying of the substrates is realized. In addition,

operations and effects are realized which are similar to those of claim 1.

When the method for drying substrate of claim 3 is employed, the method intermittently introduces the drying fluid within the processing container. Therefore, increase in consumption quantity of the drying fluid following the supplying of the drying fluid in a liquid condition is suppressed. In addition, operations and effects are realized which are similar to those of claim 1 or claim 2.

When the device for drying substrate of claim 4 is employed, the device houses substrates within the processing container, and the device dries the surface of each substrate by relatively lowering the fluid face of cleaning fluid within the processing container with respect to the substrate and by introducing the drying fluid within the processing container.

During this operation, the drying fluid supplying means introduces drying fluid under a liquid condition within the processing container, and injects the introduced drying fluid onto the fluid face of the cleaning fluid using a nozzle.

Therefore, the drying fluid is smoothly introduced between the substrates due to the influence of dead weight of the liquid drying

fluid so that the drying fluid is supplied with higher density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid is generated on the cleaning fluid so that drying of the substrates with greatly little drying mark is rapidly realized using MARANGONI effect. Further, the drying fluid is supplied in a liquid phase condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid.

Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a result, decrease in cost is realized.

When the device for drying substrate of claim 5 is employed, the device further comprises blowing means for blowing inert gas for atomizing the drying fluid, the blowing means being near the drying fluid supplying means. Therefore, disadvantage is prevented from occurrence that droplet of the injected liquid drying fluid becomes too large, so that superior drying of the substrates is realized. In addition, operations and effects are realized which are similar to those of claim 4.

When the device for drying substrate of claim 6 is employed, the device further comprises control means for controlling the drying fluid supplying means so as to intermittently introduce the drying fluid within the processing container. Therefore, increase in consumption quantity of the drying fluid following the supplying of the drying fluid in a liquid condition is suppressed. In addition, operations and effects are realized which are similar to those of claim 4 or claim 5.

When the method for drying substrate of claim 7 is employed, the method houses substrates within the processing container, and dries the surface of each substrate by relatively lowering the fluid face of cleaning fluid within the processing container with respect to the substrate and by introducing the drying fluid within the processing container. During this operation, the method conveys liquid drying fluid to exhaust opening of the nozzle using carrier gas, and the method simultaneously blows the drying fluid and the carrier gas from the exhaust opening towards the upper face of the cleaning fluid.

Therefore, the drying fluid is smoothly introduced between the substrates due to the

influence of dead weight of the liquid drying fluid so that the drying fluid is supplied with higher density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid is generated on the cleaning fluid so that drying of the substrates with greatly little drying mark is rapidly realized using MARANGONI effect. Further, the drying fluid is supplied in a liquid phase condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid.

Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a result, decrease in cost is realized.

Furthermore, the blowing quantity of the drying fluid from the blowing opening of the nozzle is suppressed so that the drying fluid of proper quantity is supplied to the dipping boundary face of the substrates. Consequently, usage quantity of the drying fluid is decreased and the running cost is decreased.

When the device for drying substrate of claim 8 is employed, the device houses substrates within the processing container, and the device dries the surface of each substrate

by relatively lowering the fluid face of cleaning fluid within the processing container with respect to the substrate and by introducing the drying fluid within the processing container. During this operation, the drying fluid supplying means conveys liquid drying fluid to exhaust opening of the nozzle using carrier gas, and simultaneously blows the drying fluid and the carrier gas from the exhaust opening towards the upper face of the cleaning fluid.

Therefore, the drying fluid is smoothly introduced between the substrates due to the influence of dead weight of the liquid drying fluid so that the drying fluid is supplied with higher density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid is generated on the cleaning fluid so that drying of the substrates with greatly little drying mark is rapidly realized using MARANGONI effect. Further, the drying fluid is supplied in a liquid phase condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid. Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a

result, decrease in cost is realized. Furthermore, the blowing quantity of the drying fluid from the blowing opening of the nozzle is suppressed so that the drying fluid of proper quantity is supplied to the dipping boundary face of the substrates. Consequently, usage quantity of the drying fluid is decreased and the running cost is decreased.

When the device for drying substrate of claim 9 is employed, the drying fluid supplying means comprises a first feed pipe for supplying carrier gas to the nozzle and a second feed pipe for supplying liquid drying fluid which is communicated to the halfway of the first feed pipe. Therefore, the blowing quantity of the drying fluid from each blowing opening is determined to be a proper quantity so that the consumption quantity of the drying fluid is decreased and the cost is decreased. In addition, operations and effects are realized which are similar to those of claim 8.

When the device for drying substrate of claim 10 is employed, the drying fluid supplying means comprises a first feed pipe for supplying carrier gas to the nozzle and a second feed pipe for supplying liquid drying fluid to the nozzle, the first feed pipe and the second feed pipe

being independently provided from one another. Therefore, the liquid drying fluid is guided by the carrier gas to the blowing opening within the nozzle. In addition, operations and effects are realized which are similar to those of claim 8.

### Brief Description of the Drawings

Figure 1 is a schematic perspective view of a device for drying substrate of an embodiment according to the present invention;

Figure 2 is a schematically vertical cross sectional view illustrating another arrangement of an injection nozzle;

Figure 3 is a schematic vertical cross sectional view illustrating a further arrangement of an injection nozzle;

Figure 4 is a schematic vertical cross sectional view illustrating yet another arrangement of an injection nozzle;

Figure 5 is a schematic perspective view of a device for drying substrate of another embodiment according to the present invention;

Figure 6 is a schematic perspective view of a device for drying substrate of a further embodiment according to the present invention;



Figure 7 is a schematic perspective view of a device for drying substrate of yet another embodiment according to the present invention;

Figure 8 is a schematic perspective view of a device for drying substrate of a yet further embodiment according to the present invention;

Figure 9 is a timing chart useful in understanding intermittent introduction of drying fluid and intermittent blowing of high temperature nitrogen gas;

Figure 10 is a perspective view illustrating a main portion of a device for drying substrate of a further embodiment according to the present invention;

Figure 11 is a perspective view illustrating a main portion of a device for drying substrate of yet another embodiment according to the present invention; and

Figure 12 is a perspective view illustrating a main portion of a device for drying substrate of a yet further embodiment according to the present invention.

### Best Mode for Carrying Out the Invention

Hereinafter, referring to the attached drawings, we explain a method and device for

drying substrate of an embodiment according to the present invention in detail.

Fig. 1 is a schematic perspective view of a device for drying substrate of an embodiment according to the present invention.

The device for drying substrate has a processing container 3 for housing a plurality of substrate 1, and for discharging cleaning fluid (for example, pure water) 2 which has cleaned the substrates 1. The device also has a feed pipe 4 for supplying liquid drying fluid (for example, IPA), and an injection nozzle 5 for injecting the drying fluid which is provided at the end section of the feed pipe 4. Of course, the injection nozzle 5 is disposed above the substrate 1.

Operation of the device for drying substrate having the above arrangement is as follows.

After the substrates 1 has cleaned by housing the cleaning fluid 2 within the processing container 3 in which the substrates 1 are housed therein, the fluid face of the cleaning fluid 2 is lowered by discharging the cleaning fluid 2 from the processing container 3 and the drying fluid is supplied through the feed pipe 4 and is injected by the injection nozzle 5. As a result, a fluid layer of the

injected drying fluid is formed on the surface of the cleaning fluid 2 so that portions exposed from the surface of the cleaning fluid 2 among the plurality of substrate 1 are rapidly dried without drying mark due to MARANGONI effect.

When portions to some degree among the plurality of substrate 1 are positioned above the surface of the cleaning fluid 2, mist conditioned drying fluid injected from the injection nozzle 5 smoothly intrudes into the clearance between substrates 1 by the dead weight thereof so that a fluid layer of the injected drying fluid is formed on the surface of the cleaning fluid 2 for those portions. Therefore, rapid drying without drying mark due to MARANGONI effect is continued.

When the above series of drying operation is carried out, almost drying fluid supplied in liquid condition is discharged with the cleaning fluid 2 from the processing container 3 to outer section so that the drying fluid scarcely leaks neighboring sections with respect to the processing container 3. As a result, an exhausting equipment for exhausting the drying fluid is eliminated or simplified so as to realize decrease in cost.

Fig. 2 is a schematic vertical cross sectional view illustrating another arrangement of an injection nozzle 5.

The injection nozzle 5 is surrounded by an inert gas blowing nozzle 6 for blowing inert gas (for example, nitrogen gas) therefrom.

When the injection nozzle 5 having the above arrangement is employed, nitrogen blowing is carried out as inert gas blowing against the injected drying fluid so that the injected drying fluid is prevented from becoming too large in size. Therefore, drying of the substrates 1 with high quality is realized. Wherein, the nitrogen gas may be the nitrogen gas with usual temperature, but the nitrogen gas is preferable to be the nitrogen gas with increased temperature of about 100 °C so as to improve the above operation and effect.

Fig. 3 is a schematic vertical cross sectional view illustrating a further arrangement of an injection nozzle 5.

The injection nozzle 5 surrounds an inert gas blowing nozzle 6 for blowing inert gas therefrom.

When the injection nozzle 5 having the above arrangement is employed, operation and effect are realized which are similar to those of the

case in which the injection nozzle 5 illustrated in Fig. 2 is employed.

Fig. 4 is a schematic vertical cross sectional view illustrating yet another arrangement of an injection nozzle 5.

The injection nozzle 5 injects the drying fluid in a horizontal direction, and an inert gas blowing nozzle 6 is provided for blowing nitrogen gas with usual temperature or high temperature as inert gas from an upper position with respect to the injected drying fluid.

When the injection nozzle 5 having the above arrangement is employed, operation and effect are realized which are similar to those of the case in which the injection nozzle 5 illustrated in Fig. 2 is employed.

Fig. 5 is a schematic perspective view of a device for drying substrate of another embodiment according to the present invention.

The device for drying substrate is different from the embodiment illustrated in Fig. 1 in that the injection nozzle 5 having the arrangement of one of Figs. 2 ~ 4 is employed, and that an exhausting slit opening 3b is provided at a predetermined position of a cover body 3a of the processing container 3.

When the device for drying substrate having the above arrangement is employed, steady flow of the inert gas is formed by exhausting the inert gas through the exhausting slit opening 3b which inert gas is introduced within the processing container 3 by inert gas blowing. Consequently, the injected drying fluid is prevented from becoming too large in size. As a result, rapid drying without drying mark of the substrates 1 is realized.

When the above arrangement is employed, there is a possibility that the drying fluid is exhausted through the exhausting slit opening 3b. But, the quantity of the drying fluid exhausted through the exhausting slit opening 3b is remarkably small so that disadvantage does not arise, because almost drying fluid is injected towards the surface of the cleaning fluid 2 so as to form the fluid layer on the surface.

Fig. 6 is a schematic perspective view of a device for drying substrate of a further embodiment according to the present invention.

The device for drying substrate is different from the embodiment illustrated in Fig. 5 in that an exhausting slit opening 3b is provided at an upper section of a side wall of the processing container 3.

When this arrangement is employed, operation and effect are realized which are similar to those of the device for drying substrate illustrated in Fig. 5.

Fig. 7 is a schematic perspective view of a device for drying substrate of yet another embodiment according to the present invention.

The device for drying substrate is different from the embodiment illustrated in Fig. 5 in that an exhausting pipe 3c is provided at a predetermined position of a cover body 3a of the processing container 3.

When this arrangement is employed, leakage of the drying fluid is securely prevented. In addition, operation and effect are realized which are similar to those of the device for drying substrate illustrated in Fig. 5.

Fig. 8 is a schematic perspective view of a device for drying substrate of a yet further embodiment according to the present invention.

The device for drying substrate is different from the embodiment illustrated in Fig. 5 in that an opening and closing valve 4a is provided at a predetermined position of the feed pipe 4 for supplying drying fluid to the injection nozzle 5, that an opening and closing valve 7a is provided at a predetermined position of a

feed pipe 7 for supplying nitrogen gas to the nitrogen gas blowing nozzle 6, and that a valve control section 8 is provided for controlling the opening and closing valves 4a and 7a.

When the device for drying substrate having the above arrangement is employed, the drying fluid is intermittently introduced within the processing container 3 by periodically opening and closing the opening and closing valve 4a. Therefore, consumption quantity of the drying fluid is decreased in comparison with consumption quantity of the drying fluid when it is continuously introduced.

Specifically, as is illustrated in Fig. 9 for example, injection of the drying fluid is carried out for 0.5 seconds, then blowing of only the nitrogen gas with high temperature is carried out for 2 seconds, thereafter the valve control section 8 controls both opening and closing valves 4a and 7a so as to repeat the injection of the drying fluid and the blowing of only the nitrogen gas with high temperature. When this operation is carried out, the consumption quantity of the drying fluid and the consumption quantity of the nitrogen gas with high temperature are decreased in comparison with the consumption quantity of the drying



fluid and the consumption quantity of the nitrogen gas with high temperature when the drying fluid is continuously introduced and when the nitrogen gas with high temperature is continuously blown for atomizing the drying fluid. The decreasing rate of the consumption quantity of the drying fluid is about 80%, while the decreasing rate of the consumption quantity of the nitrogen gas with high temperature is about 20%.

This specific example introduces the drying fluid for 0.5 seconds at every 2.5 seconds. The introduction interval of the drying fluid and the introduction quantity of the drying fluid at every introduction can be determined following the lowering speed of the surface of the cleaning fluid for carrying out drying of the substrates due to MARANGONI effect.

In the above embodiments, the surface of the cleaning fluid 2 is lowered by discharging the cleaning fluid 2. Instead the discharging of the cleaning fluid 2, it is possible that drying is carried out following moving upward of the plurality of substrate 1.

Fig. 10 is a perspective view illustrating a main portion of a device for drying substrate of a further embodiment according to the present

invention. The arrangement of each portion which is not illustrated is similar to that of the above embodiment, therefore detailed description is omitted.

The device for drying substrate has a first feed pipe 5a for supplying carrier gas (for example, nitrogen gas) to the injection nozzle 5, and a second feed pipe 5b for supplying liquid drying fluid, the second feed pipe 5b being communicated to halfway of the first feed pipe 5a. Further, injection openings 5c of the injection nozzle 5 are determined their positions so that the injection openings 5c correspond to clearances of the substrates 1.

When the device for drying substrate of this embodiment is employed, the carrier gas is supplied to the injection nozzle 5 through the first feed pipe 5a so as to generate negative pressure at the position corresponding to the opening of the second feed pipe 5b. Consequently, the liquid drying fluid is sucked into the first feed pipe 5a due to the negative pressure, then the drying fluid is supplied to the injection nozzle 5 with the carrier gas. Then, mist of the drying fluid is blown from the injection opening 5c of the injection nozzle 5. Drying of the substrates 1 is realized by the

mist as similar as the operation of the above embodiment.

When this embodiment is employed, blowing quantity of the drying fluid from the injection nozzle 5 is suppressed so that proper amount of the drying fluid is supplied to the dipping boundary face of each substrate 1. As a result, usage quantity of the drying fluid is decreased, and the running cost is decreased.

Fig. 11 is a perspective view illustrating a main portion of a device for drying substrate of yet another embodiment according to the present invention. The arrangement of each portion which is not illustrated is similar to that of the above embodiment, therefore detailed description is omitted.

The device for drying substrate has a first feed pipe 5a for supplying carrier gas to the injection nozzle 5, the first feed pipe 5a being communicated to one end face of the injection nozzle 5 in a longitudinal direction, and has a second feed pipe 5b for supplying liquid drying fluid, the second feed pipe 5b being communicated to a face of the injection nozzle 5 which face is neighboring to the one end face. Further, injection openings 5c of the injection nozzle 5 are determined their positions so that

the injection openings 5c correspond to clearances of the substrates 1.

When the device for drying substrate of this embodiment is employed, the carrier gas is supplied to the injection nozzle 5 through the first feed pipe 5a so that the inner pressure within the injection nozzle 5 becomes high pressure because the injection openings 5c are small in size. And, liquid drying fluid is supplied into the injection nozzle 5 by supplying the liquid drying fluid with higher pressure with respect to the inner pressure through the second feed pipe 5b. Then, mist of the drying fluid is blown from the injection openings 5c of the injection nozzle 5. Drying of the substrates 1 is realized by the mist as similar as the operation of the above embodiment.

When this embodiment is employed, blowing quantity of the drying fluid from the injection nozzle 5 is suppressed so that proper amount of the drying fluid is supplied to the dipping boundary face of each substrate 1. As a result, usage quantity of the drying fluid is decreased, and the running cost is decreased.

Fig. 12 is a perspective view illustrating a main portion of a device for drying substrate of a yet further embodiment according to the

present invention. The arrangement of each portion which is not illustrated is similar to that of the above embodiment, therefore detailed description is omitted.

The device for drying substrate is different from the device for drying substrate illustrated in Fig. 11 in that an exhaust pipe 5d is provided for exhausting carrier gas, the exhausting pipe 5d being communicated with the other end face of the injection nozzle 5 in a longitudinal direction, that a valve 5e is provided at a predetermined position of the exhausting pipe 5d, and that the second feed pipe 5b is communicated with the injection nozzle 5 only at the most upstream side thereof.

When this embodiment is employed, the rate of the carrier gas blown from the injection openings 5c and the carrier gas exhausted through the exhausting pipe 5d is controlled by controlling the opening of the valve 5e. The liquid drying fluid supplied to the injection nozzle 5 through the second supplying is accelerated by the carrier gas, and the liquid drying fluid is supplied in the entire extent from the most upstream side injection opening 5c to the most downstream side injection opening 5c, so that mist of drying fluid is blown from every

injection opening 5c. Of course, the blown drying fluid is made to be fine mist by the carrier gas. Therefore, drying of the substrates 1 with high quality is realized.

### Industrial Applicability

The present invention can be applied to the drying of substrates such as semiconductor wafers or the like. Drying of the substrates with high quality is realized.

What Is Claimed Is:

1. A method for drying substrate is a method which houses substrates (1) within a processing container (3), and dries a surface of each substrate (1) by relatively lowering a fluid face of cleaning fluid (2) within a processing container (3) with respect to the substrate (1) and by introducing the drying fluid within the processing container (3), the method comprising the steps of;

Introducing drying fluid under a liquid condition within the processing container (3), and

Injecting the introduced drying fluid onto the fluid face of the cleaning fluid (2) using a nozzle (5).

2. A method for drying substrate as set forth in claim 1, further comprising the step of blowing inert gas for atomizing the drying fluid.

3. A method for drying substrate as set forth in claim 1 or claim 2, introducing drying fluid within the processing container (3) is carried out intermittently.

4. A device for drying substrate is a device which houses substrates (1) within a processing container (3), and dries a surface of

each substrate (1) by relatively lowering a fluid face of cleaning fluid (2) within a processing container (3) with respect to the substrates (1) and by introducing the drying fluid within the processing container (3), the device comprising;

Drying fluid supplying means (4) (4a) (5) for introducing drying fluid under a liquid condition within the processing container (3), and for injecting the introduced drying fluid onto the fluid face of the cleaning fluid (2) using a nozzle (5).

5. A device for drying substrate as set forth in claim 4, further comprising blowing means (6) for blowing inert gas for atomizing the drying fluid, the blowing means (6) being near the drying fluid supplying means (5).

6. A device for drying substrate as set forth in claim 4 or claim 5, further comprising control means (8) for controlling the drying fluid supplying means (4a) so as to intermittently introduce the drying fluid within the processing container (3).

7. A method for drying substrate is a method which houses substrates (1) within a processing container (3), and dries a surface of each substrate (1) by relatively lowering a



fluid face of cleaning fluid (2) within a processing container (3) with respect to the substrate (1) and by introducing the drying fluid within the processing container (3), the method comprising the steps of;

Conveying liquid drying fluid to exhaust opening (5c) of a nozzle (5) using carrier gas, and

Simultaneously blowing the drying fluid and the carrier gas from the exhaust opening (5c) towards an upper face of the cleaning fluid (2).

8. A device for drying substrate is a device which houses substrates (1) within a processing container (3), and dries a surface of each substrate (1) by relatively lowering a fluid face of cleaning fluid (2) within a processing container (3) with respect to the substrate (1) and by introducing the drying fluid within the processing container (3), the device comprising;

Drying fluid supplying means (5) (5a) (5b) (5c) for conveying liquid drying fluid to exhaust opening (5c) of a nozzle (5) using carrier gas, and for simultaneously blowing the drying fluid and the carrier gas from the exhaust opening (5c) towards an upper face of the cleaning fluid (2).

9. A device for drying substrate as set forth in claim 8, wherein the drying fluid supplying means (5) (5a) (5b) (5c) comprises a first feed pipe (5a) for supplying carrier gas to the nozzle (5) and a second feed pipe (5b) for supplying liquid drying fluid which is communicated to the halfway of the first feed pipe (5a).

10. A device for drying substrate as set forth in claim 8, wherein the drying fluid supplying means (5) (5a) (5b) (5c) comprises a first feed pipe (5a) for supplying carrier gas to the nozzle (5) and a second feed pipe (5b) for supplying liquid drying fluid to the nozzle (5), the first feed pipe (5a) and the second feed pipe (5b) being independently provided from one another.

Fig. 1

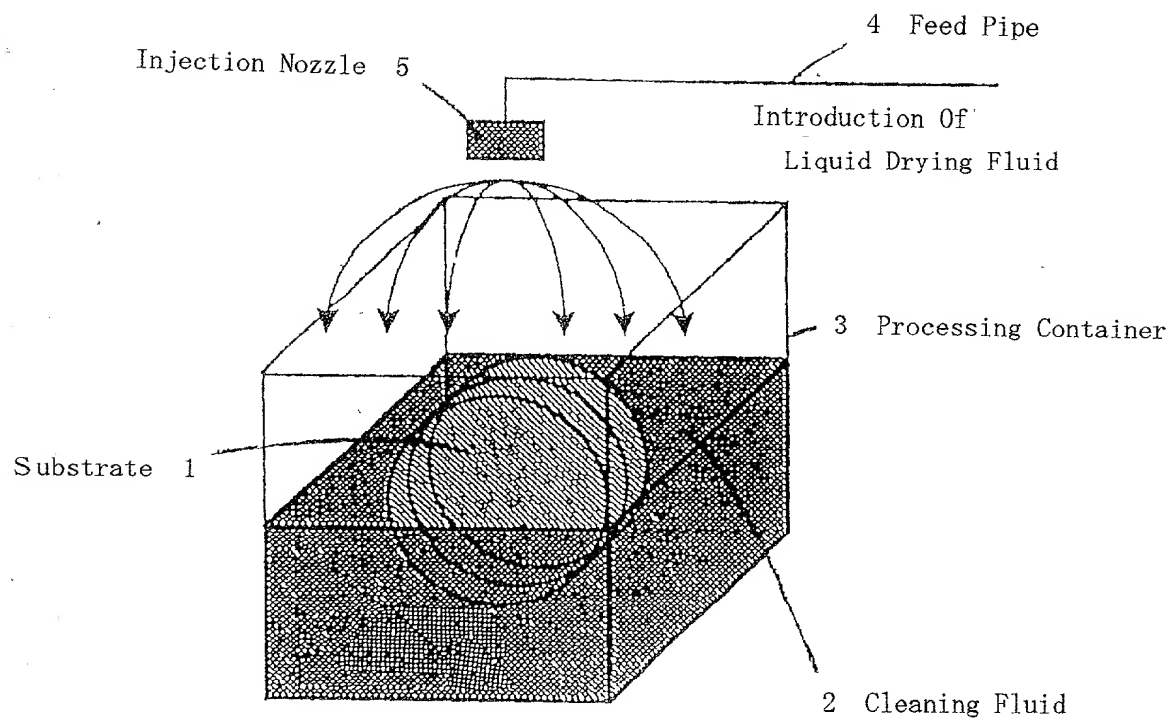


Fig. 2

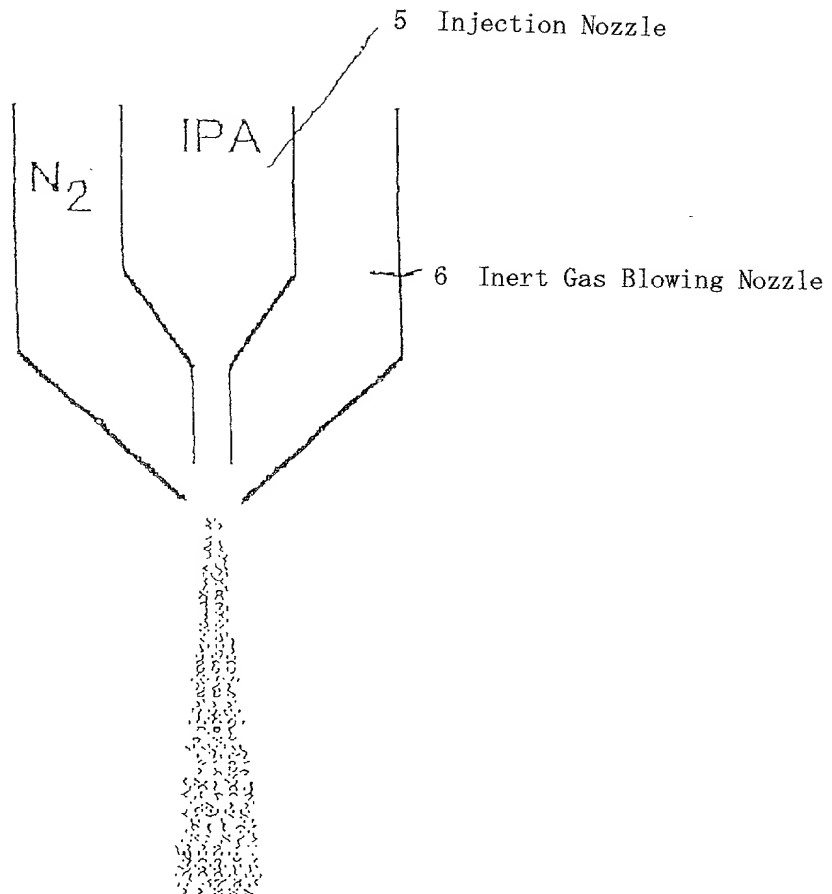


Fig. 3

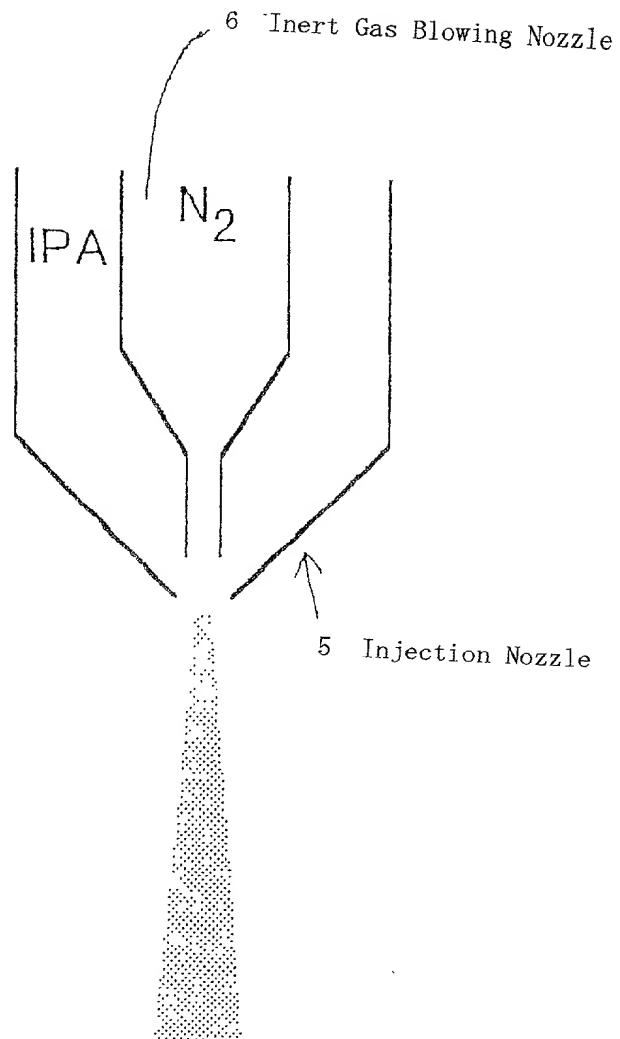


Fig. 4

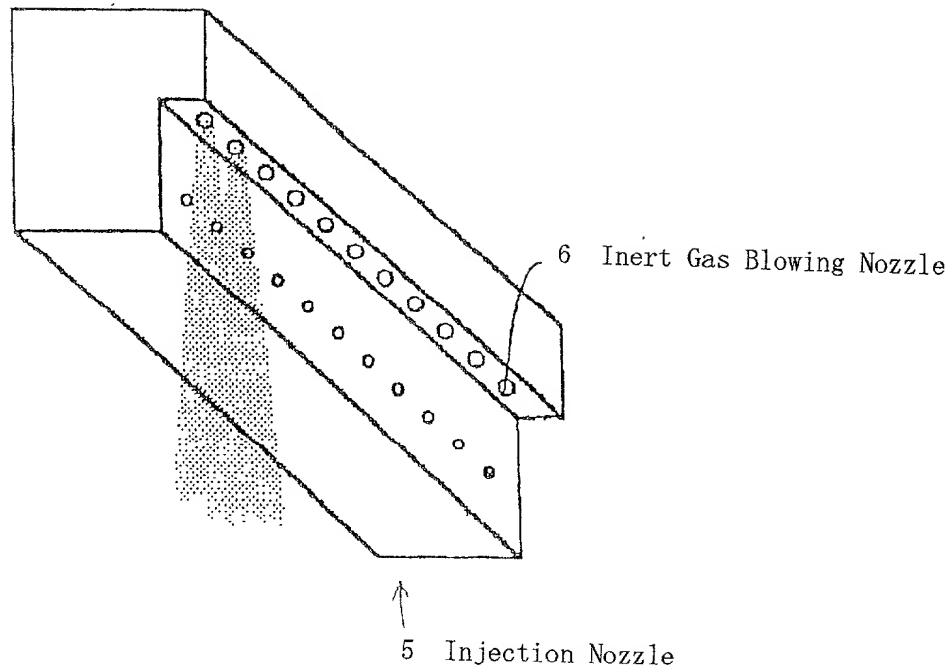


Fig. 5

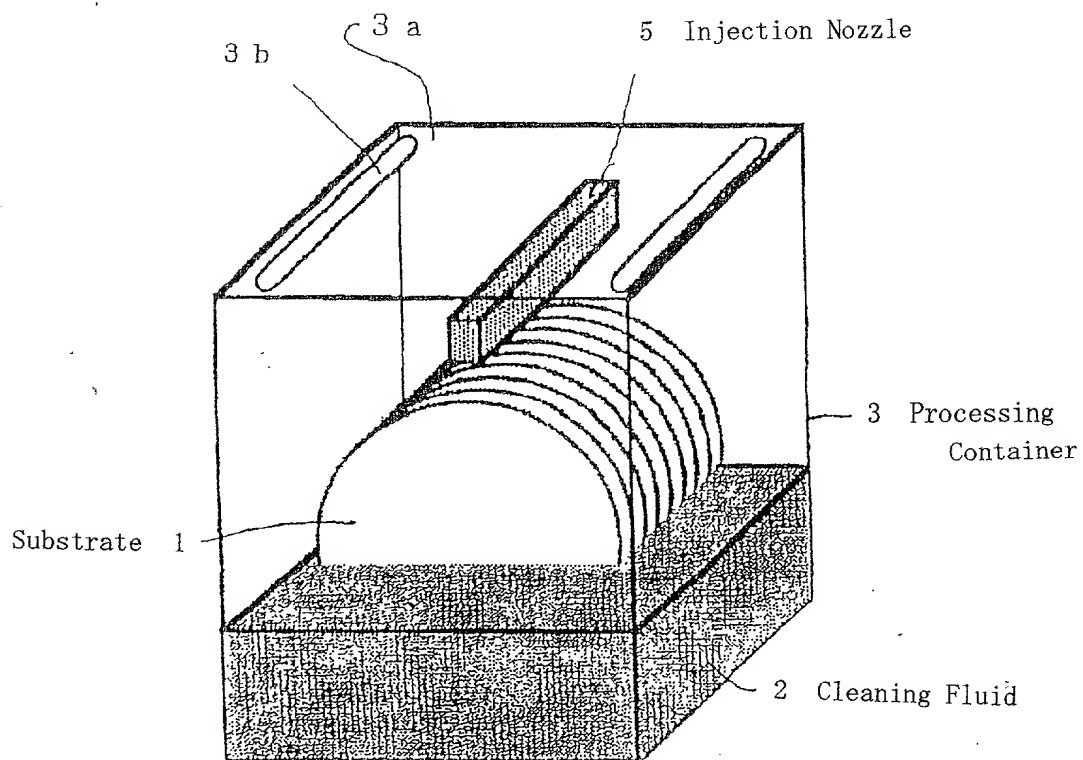


Fig. 6

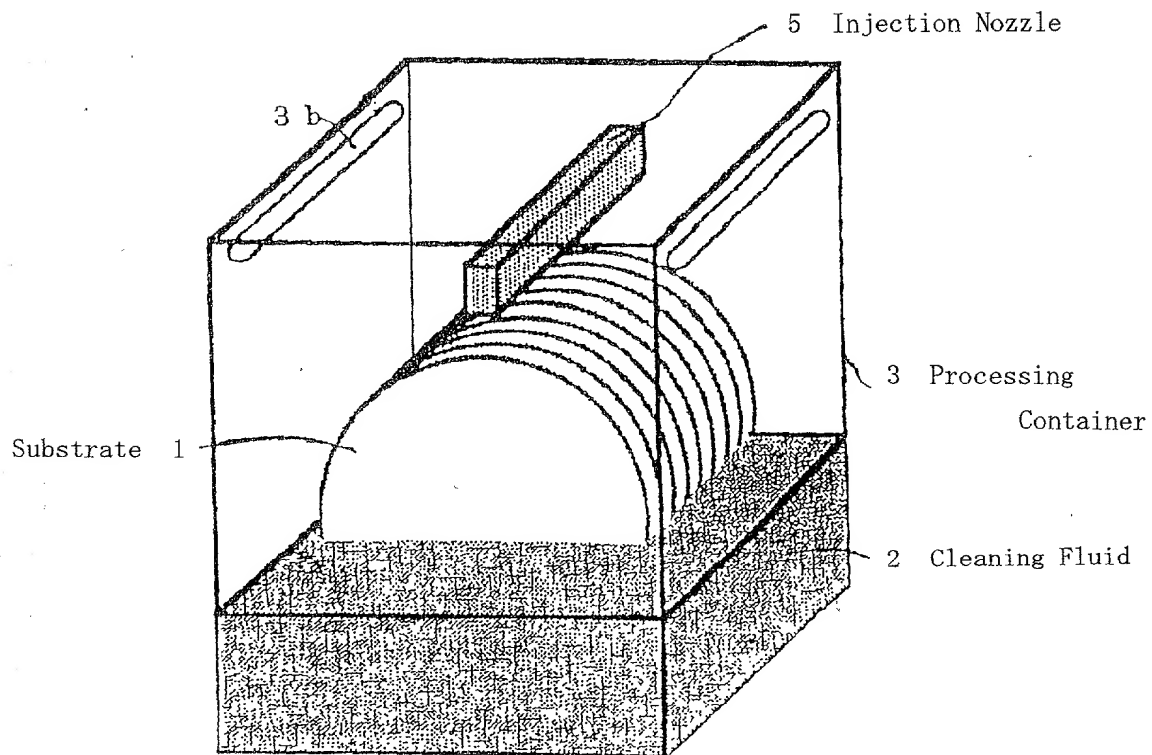


Fig. 7

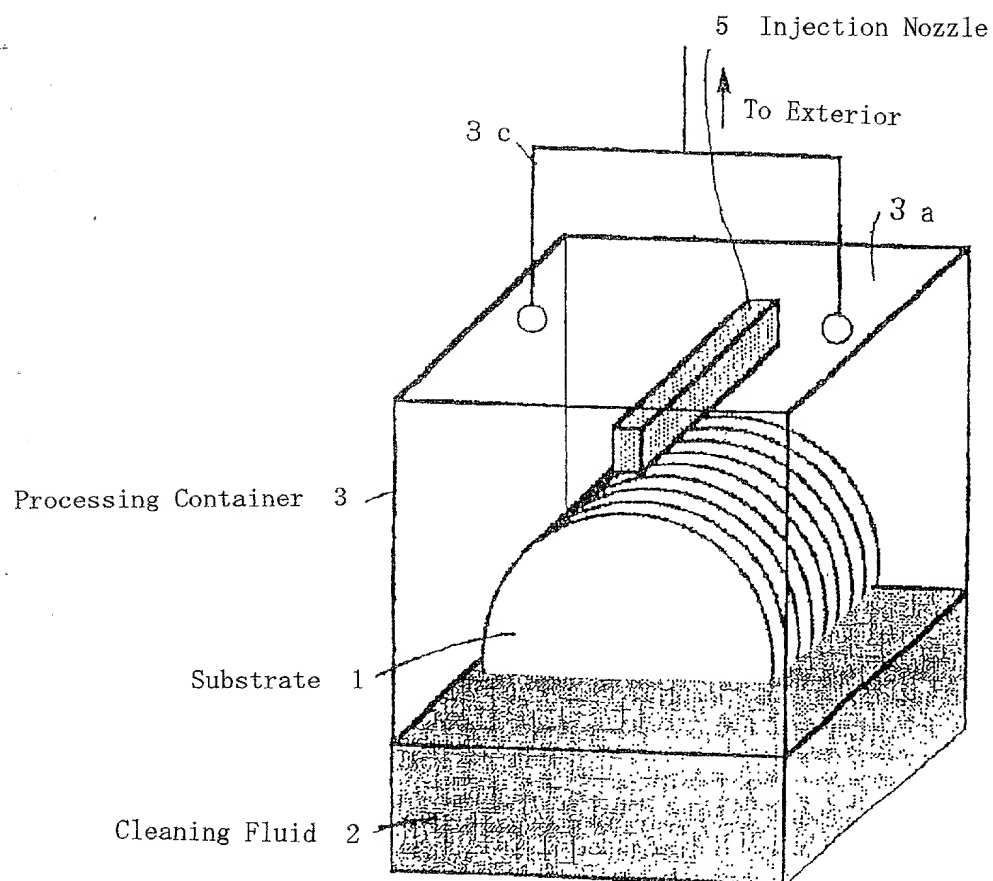




Fig. 8

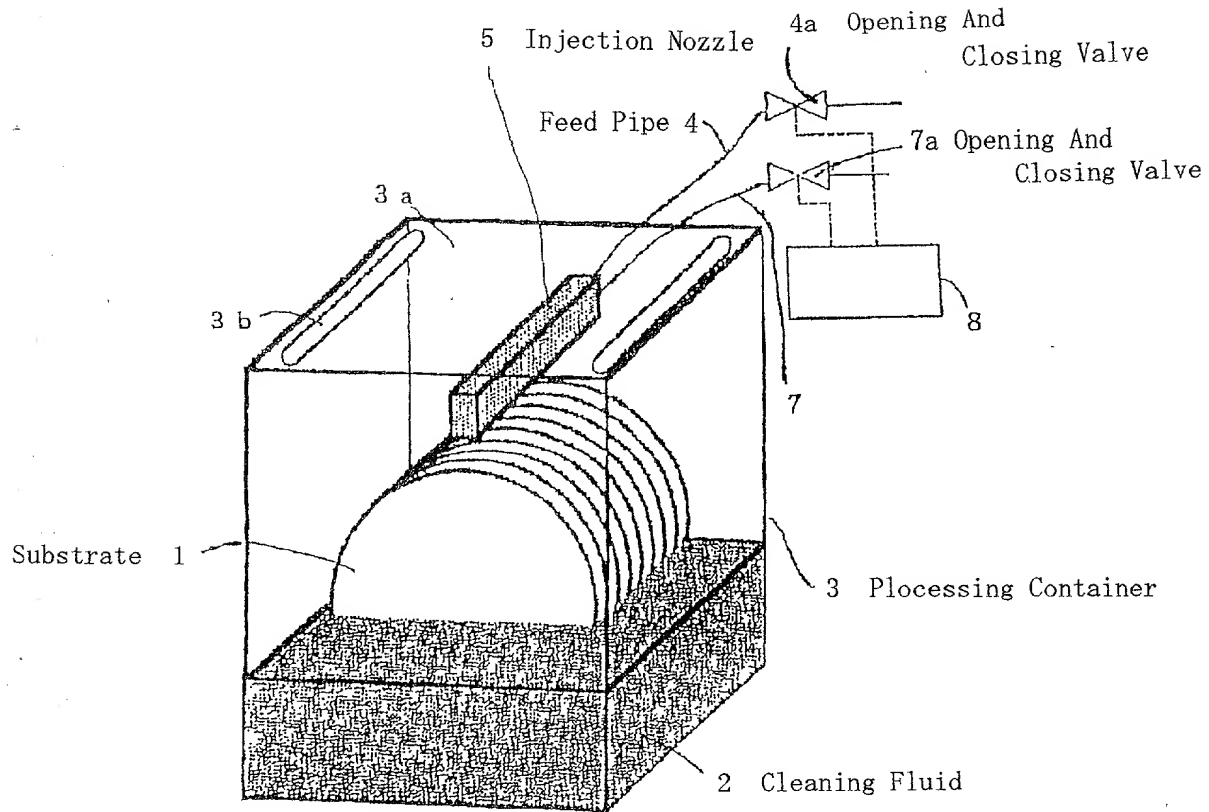


Fig. 9

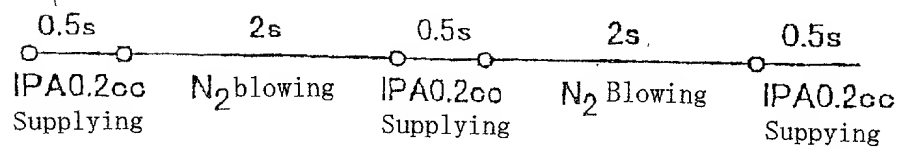


Fig. 10

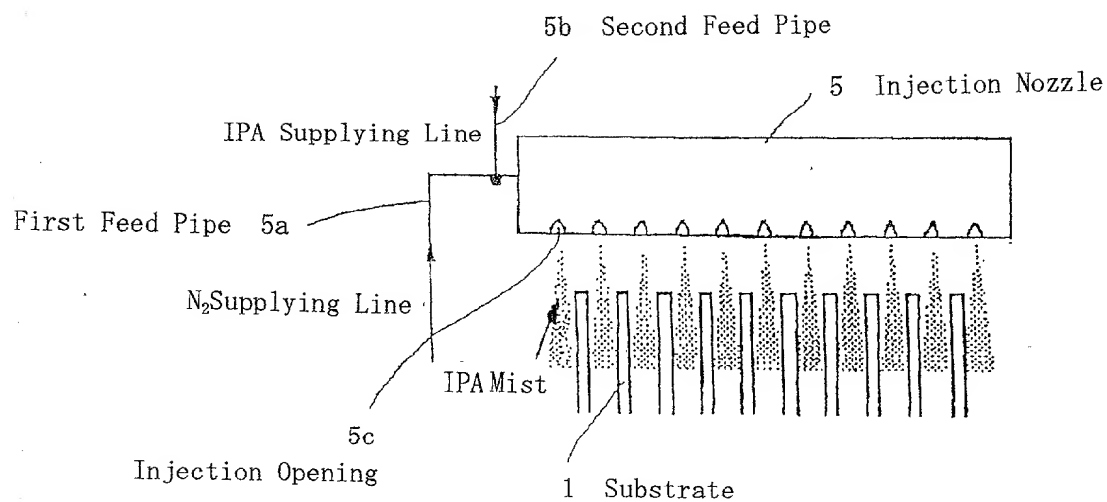


Fig. 11

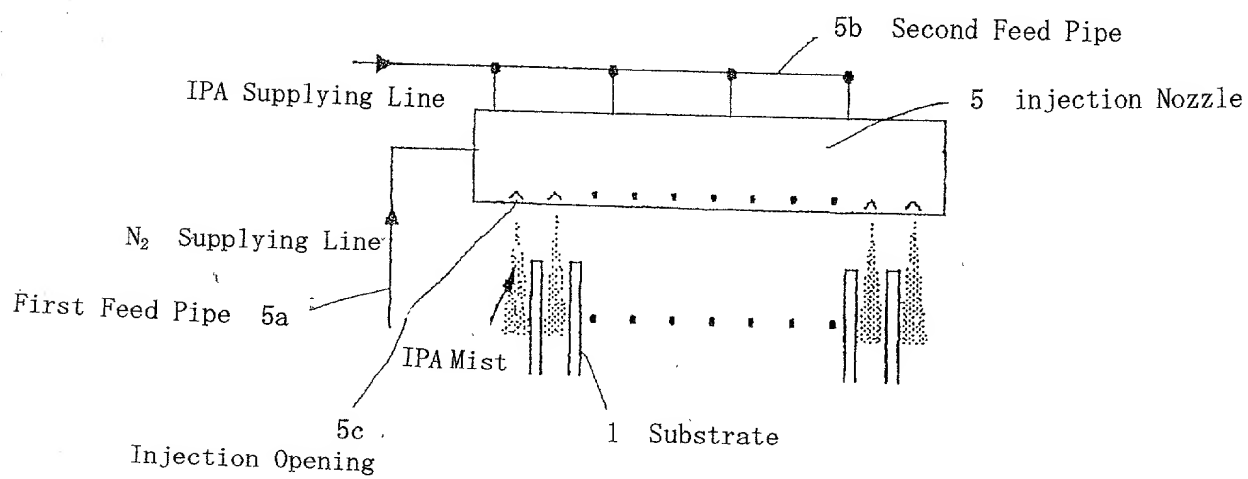
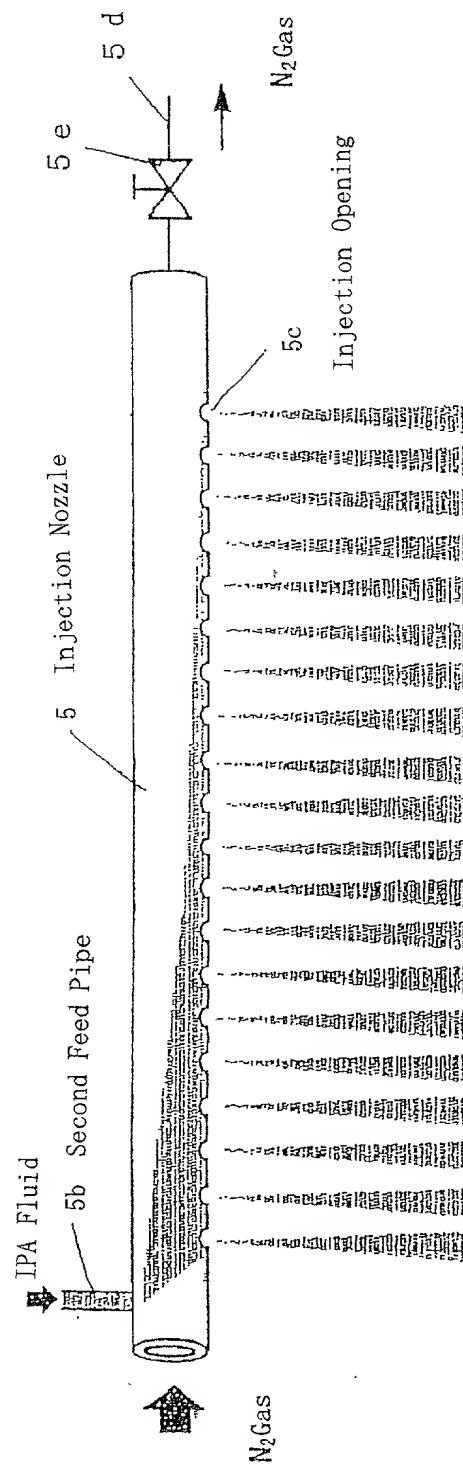


Fig. 12



# Declaration and Power of Attorney United States Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent

is sought on the invention entitled

Method and device for Drying Substrate

This form cannot be amended, altered

or changed after it is signed.

(For use only for inventors who do not understand the English language.)

\_\_\_\_\_, the specification of which

(check one) ☐ is attached hereto.

☐ was filed as U.S. Application No. \_\_\_\_\_ on \_\_\_\_\_ and (if applicable) was amended on \_\_\_\_\_.

☐ was filed as PCT International Application No. \_\_\_\_\_ on \_\_\_\_\_ and (if applicable) was amended under PCT Article 19 on \_\_\_\_\_.

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign and PCT application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designated at least one country other than the United States of America listed in this Declaration. I have also identified below any foreign application for patent or inventor's certificate or PCT international application having a filing date before that of the application(s) on which priority is claimed:

Foreign/PCT Application No.	Country	Filing Date	Priority Claimed?(yes/no)
PCT/JP99/04335	PCT	August 10, 1999	Yes
1999/9338	Japan	January 18, 1999	Yes
1999/122696	Japan	April 28, 1999	Yes

I hereby claim the benefit under Title 35, United States Code, § 120 or § 365(c) of any United States application and PCT international application designating the United States of America listed in this Declaration and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

U.S. Application No.	Filing Date	Status (patented/pending/abandoned?)

I hereby claim priority benefits under Title 35 United States Code § 119(e) of any U.S. provisional application(s) listed below:

U.S. Provisional Application No.	Filing Date

I hereby appoint the following attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Joseph A. DeGrandi (17446), Robert G. Weilacher (20531), Richard G. Young (20628), Michael A. Makuch (32263), Dennis C. Rodgers (32936), William F. Rauchholz (34701), G. Byron Stover (34737), Thomas L. Evans (35805), Maurice U. Cahn (30454), and William J. Bunderen (31712).

Send all correspondence to Beveridge, DeGrandi, Weilacher & Young, Suite 800, 1850 M Street, N.W., Washington, D.C. 20036. Facsimiles may be sent to (202) 659-1462. Direct all telephone calls to (202) 659-2811.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: Norio MAEDA

Residence (city, state, country): Yamatokouriyama-shi, Nara 639-1031 Japan

Post office address: C/O TOHO KASEI LTD., 6-2, Imakokubu-cho, Yamatokouriyama-shi, Nara 639-1031 Japan

Citizenship: JAPAN

Signature: Norio MAEDA Date: 2001. 12. 7

## Additional Inventor(s):

I hereby declare that all statements made in the attached Declaration and Power of Attorney of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of inventor: Koji SUMI <sup>2-a</sup> Citizenship: JAPAN  
 Residence(city, state, country): Yamatokouriyama-shi, Nara 639-1031 Japan JPX  
 Post office address: C/O TOHO KASEI LTD., 6-2, Imakokubu-cho, Yamatokouriyama-shi, Nara 639-1031 Japan

Signature: Koji SUMI Date: \_\_\_\_\_

Full name of inventor: Hiroshi AIHARA <sup>3-a</sup> Citizenship: JAPAN  
 Residence(city, state, country): Sakai-shi, Osaka 591-8022 Japan JPX  
 Post office address: C/O Kanaoka koujou Sakai Seisakusho of Daikin Industries, LTD.,  
 1304 Kanaoka-cho Sakai-shi, Osaka 591-8022 Japan

Signature: Hiroshi AIHARA Date: \_\_\_\_\_

Full name of inventor: Masao OONO <sup>4-a</sup> Citizenship: JAPAN  
 Residence(city, state, country): Sakai-shi, Osaka 591-8022 Japan JPX  
 Post office address: C/O Kanaoka koujou Sakai Seisakusho of Daikin Industries, LTD.,  
 1304 Kanaoka-cho Sakai-shi, Osaka 591-8022 Japan

Signature: Masao OONO Date: \_\_\_\_\_

Full name of inventor: Naoaki IZU TANI <sup>5-a</sup> Citizenship: JAPAN  
 Residence(city, state, country): Sakai-shi, Osaka 591-8022 Japan JPX  
 Post office address: C/O Kanaoka koujou Sakai Seisakusho of Daikin Industries, LTD.,  
 1304 Kanaoka-cho Sakai-shi, Osaka 591-8022 Japan

Signature: Naoaki IZUTANI Date: \_\_\_\_\_

## Additional Foreign/PCT Applications:

Foreign/PCT Application No.	Country	Filing Date	Priority Claimer?(yes/no)

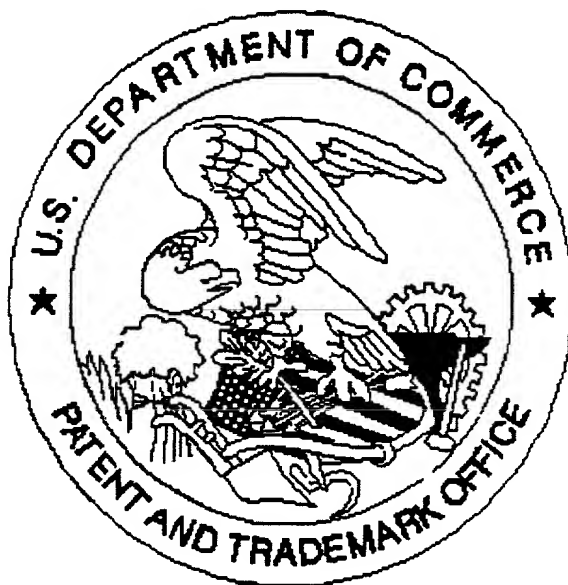
## Additional U.S. Applications:

U.S. Application No.	Filing Date	Status (patented/pending/abandoned?)

## Additional Provisional U.S. Applications:

U.S. Provisional Application No.	Filing Date

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